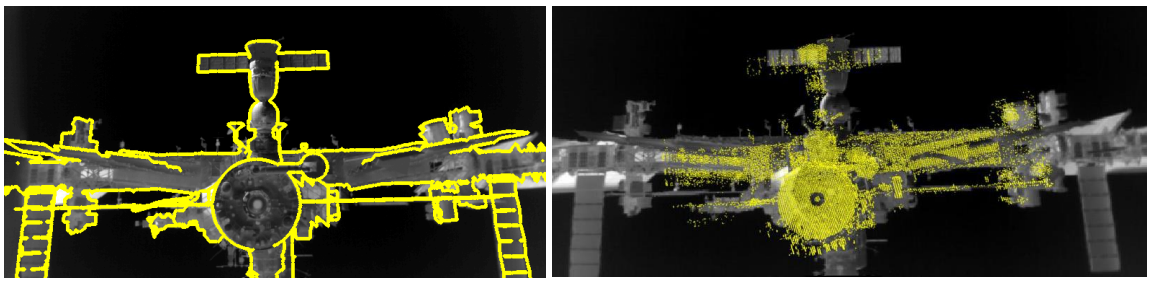
3D Reconstruction of In-orbit Satellites

Inria Internship in collaboration with Airbus

Context. A space rendezvous is an orbital maneuver during which two spacecraft, here two satellites, arrive at the same orbit and approach until contact (docking or capture). In-orbit rendezvous between two spacecraft is becoming a very fast developing space activity. It may be split into different categories: autonomous or not, with collaborative or uncooperative target. The proposed internship focuses on autonomous uncooperative rendezvous, where the target has not been designed for rendezvous (no dedicated patterns like retro-reflectors...), cannot be controlled specifically for the rendezvous (in-activity satellite) or is not controlled at all (space debris). Autonomy of rendezvous implies to assess on-board the chaser and in real time the pose of the target. Classical pose estimation solutions consist in model-based image processing, which relies upon LiDAR or camera images acquired by the chaser, as well as the 3D model of the target. While in most previous work this 3D model is considered to be known a priori, for real-world missions it can be poorly known, erroneous or even completely unknown.



Left. Example of ISS tracking in images, where the 3D model is accurately known a priori. Right. Example of LiDAR data acquired on the ISS. Both camera and LiDAR data have been acquired during the LIRIS experiment on ATV-5.

Objective. The main objective of the internship is to study the reconstruction of the 3D model of a target for rendezvous purpose, from LiDAR (laser) and camera data. The internship will start with a review of object 3D reconstruction technics from LiDAR and/or camera images. It will then assess the main challenges of reconstruction in space (satellite reflective and poorly textured surface, sensor date noise and sparsity, relative navigation errors...) and will therefore propose 3D reconstruction solutions. In particular, as satellites generally exhibit strong geometric regularities in terms of shapes, structural approaches based on the assembling of surface and/or volume primitives will be a methodology to explore first. A prototype of the most promising solution will then be developed and

evaluated on simulated and real data. This internship will be followed by a Ph.D. thesis and should hence be considered as a first step for the thesis.

Required qualification. The required qualification for this internship is a BS or MS degree in Computer Science, or equivalent. The basic requirement is a solid understanding of 3D geometry (data structures, algorithms) as well as proficiency with generic programming in C++. Familiarity with common geometry processing algorithms such as surface reconstruction is a clear plus. Similarly, previous experience with image processing as well as numerical optimization techniques and applied mathematics is highly relevant.

Internship. The internship will be hosted at Inria Sophia-Antipolis, in the TITANE project-team.

Partners.

- **Inria**. The TITANE team focuses on geometric modeling of 3D environments, and analysis of satellite images, see https://team.inria.fr/titane/. Our central research themes involve methods commonly referred to as digital geometry processing, 3D urban reconstruction (both indoor and outdoor) and advanced machine learning approaches for analysis of large-scale images. A distinctive property of the TITANE team is a synergy between geometry, computer vision and image processing techniques. We made several advances on the computerized geometric modeling of complex scenes from physical measurements.
- **Airbus**. The image processing advanced studies team of Airbus Defence and Space worked for more than 10 years on vision-based navigation solutions, aiming at providing autonomy to vehicles using vision sensors. The team has developed model-based approaches to detect and track a target, and estimate its pose using its 3D model. These approaches are currently evaluated for an on-going Airbus project of servicing vehicle.